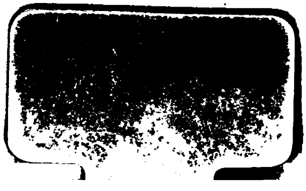
ELEMENTS

OF

NATURAL PHILOSOPHY



The Elements

OF

NATURAL PHILOSOPHY,

EXPLAINED IN A SERIES OF EASY AND PROGRESSIVE EXPERIMENTS, WITH AN INTRODUCTION ON THE METHOD OF TEACHING THE SCIENCE.

ADAPTED FROM THE GERMAN OF DR. KRUEGER,

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INTRODUCTION.

If we examine the manner in which Natural Philosophy has been hitherto treated in elementary classes, we cannot help feeling convinced that, whilst, on the one hand, it has been treated too superficially, on the other, it has not been attended by that success which the subject seems to promise.

In some schools, out of the whole department of Natural Philosophy, only the most common phenomena of *weather* are explained, and that, too, in a manner which must be superficial, if it were only because all groundwork upon which explanations of those occurrences can be founded, is entirely wanting. In others, the so-called "*general properties*" form the subject of exposition in this course. In a third, the schoolmaster has, perhaps, by a fortunate chance, become possessed of some physical instrument—say, an air-pump; this induces him to fill up the time allotted to Natural Philosophy with the same experiments year after year, whilst all other physical phenomena are only slightly touched upon, "because the necessary apparatus is wanting."

Lastly, because the whole department of Natural Philosophy is too large for one course; other teachers make a practice of teaching, at great length, some one particular branch of the science; and the necessary apparatus for illustrating the minor parts of that branch being wanting, the schoolmaster is fain to supply its place by diagrams, &c., which are but a poor substitute.

Thus, two extremes are met with, not only as to the manner of treating the subject itself, but also as to the limits within which it is kept. With some it is restricted to an infinitesimal minimum; in others it is treated on a scale which would require several years to complete the course—a method consequently presenting to the pupils but fragmentary portions of the science.

We are, therefore, going to point out the principles which, it appears to us, should guide us in limiting and defining the proper amount to be exhibited in a first and elementary course.

FIRST.—In respect to what should be excluded from such a course, we should *expunge* :—

A.—All mathematics not absolutely essential. Although the efforts for rescuing Natural Philosophy from an exclusively mathematical treatment (to which at one time we appeared to be in danger of being confined) have been very successful, still there are some parts necessarily requiring the aid of mathematics, and which, without them, could not be clearly explained. Of these parts, only such will find a place in an elementary course which can be

treated in an elementary manner; all others must be omitted. For example: 1,—the formula. $v^2 = 2gs$, and others, connected with the laws of falling bodies; 2,—all mathematics pertaining to projectiles, and to bodies acted on, by central forces; 3,—the inclined plane from a mathematical point of view; 4,—the specific statement of the proportions between the pitch of a note, the number of vibrations, and the length of the vibrating chord; 5, —the details about the images produced by mirrors and lenses; 6,—the mathematical expression of the law of refraction, viz., $\sin \theta = \mu \sin \phi$; 7,—the minute mathematical statements in connection with the rainbow.

In setting forth this principle, we do not, of course, mean either to deny or to overlook the great service that mathematics have rendered to Natural Philosophy; we only mean to say that, teaching Natural Philosophy from a mathematical point of view, prevents the beginner from looking upon it as an experimental science; and that it is not necessary to make any direct use of mathematics in an elementary course.

B.—All philosophical toys. There is considerable danger of falling into the practice of occupying much time with an exhibition of curious or frivolous applications of mechanical principles—philosophical toys, in fact—to the exclusion of many important parts of the subject. There is scarcely a single elementary text-book in which the Chinese tumblers and Cartesian diver, &c. are not described at length. Many things, even, which are of import-

ance in the science, are to be looked upon as toys in this course, as, for instance, the sound-figures of Chladni. We must have much time to give to the subject, if we mean to show and explain these numerous play-things. Just as much as those toys which are only found in physical cabinets, and which are interesting from their form and novelty, are to be excluded—just as little, on the other hand, are we to pass over such play-things as are in possession of most of the pupils, and which have obtained some degree of popularity amongst them. In such cases all that is important is, to show the action of the laws of nature in each particular instance, and to make the toy a subject for reflection.

C.—All complicated experiments and apparatus. Every branch of natural science has reached a degree of perfection, of which even educated men have little idea. Works on Natural Philosophy, in particular, describe a great number of experiments which many people never have an opportunity of seeing, and physical cabinets are rich in apparatus whose structure and purpose will always be to the uninitiated a book with seven seals. "Amongst the causes," says Becquerel, "which for a long while have prevented, and still prevent, Natural Philosophy from being more studied by the people, may be reckoned the luxury exhibited in instruments serving to illustrate lectures on this subject." Happily such costly machines are not to be easily had; yet we often hear the expense of these apparatus complained of as an

evil, by persons who attempt to supply their place by diagrams.

It is true, instruction in physics is not to be given without some illustrations or other, but there is no necessity to resort to complicated apparatus and experiments. There is no lack of contrivances, in common life, which would furnish the requisite insight into the laws of nature, and where this is the case, the use of expensive machinery is to be carefully guarded against. Many more persons would learn this interesting branch of science, if it were less dependent on technical apparatus; if, at the same time, the teacher exercised his ingenuity a little in making simple contrivances, exhibiting the same laws, and did not content himself with mere descriptions.

SECONDLY.—Whilst the matter to be taught in an elementary course is to be restricted according to the principles just advanced, on the other hand, the usual plan may be in some respects advantageously *enlarged*:—

A.—The phenomena of the weather should take a more prominent place in this course than has hitherto been assigned to it. The commoner any occurrence in the weather is, the more necessary is it, that a simple explanation should be presented to every pupil,—even the lowest. So we must bring forward all those portions of the subject, without which an explanation of these phenomena would be impossible. Thus, *e.g.*, the theory of frictional electricity would not form a part of this course, if lightning were not an electrical phenomenon.

B.—The more common tools and instruments in daily use, so far as they do not belong to mere technology, deserve a greater consideration; yet Natural Philosophy must not wander into the shop of the engineer, any more than it is obliged to enter into an explanation of the construction of spinning machines and looms; nor is it to take in detail the tools of any particular craft. On the other hand, there are practical applications which are interesting and important in general life, which are used everywhere in commerce, and of which a person must, without seeking for them, take cognizance of, provided he makes use of his senses. Such are the common pump, the fire-engine, balances, lightning-conductors, spectacles, &c.

C.—Reference to simple experiments and well-known phenomena. Thus, in order to explain the expansion of solid bodies, we do not need to bring forward a pyrometer, it is sufficient to recollect the red-hot heater of a tailor's goose; nor do we require Wollaston's cryophorus, or the artificial production of ice by means of an air-pump, in order to prove the fact that cold is produced by evaporation; we need only remind ourselves of the cold of wet rooms, and of the result of wearing damp clothes. With a glass of water we are able to explain very distinctly the laws of cohesion, the refraction of the rays of light, the diving-bell, and the weight and elasticity of air.

The following is a synopsis of the course of Natural

Philosophy, drawn out on the above principles, and will furnish a syllabus of the contents of the book:—

I.—Of Equilibrium and Motion.

1, *Solid bodies.*

Bodies falling, and sliding down inclined planes by gravitation; the plumbline; the lever, and the pulley; the balance, and phenomena referable to the balance.

2, *Fluid bodies.*

The flowing of a stream of water, and the horizontal position of its surface when at rest, as effects of gravitation; fountains; the phenomena of adhesion; and floating of bodies.

3, *Gaseous bodies.*

Suction; respiration; simple experiments for the pressure of the air; the pump; the firé-engine; the barometer; and the diving-bell.

II.—Of Sound.

Origin and propagation of sound; echo.

III.—Of Light.

The rectilineal propagation of light; shadows; the more common applications of mirrors; twilight; reference to refraction; spectacles; telescopes and photographs; composition of sunlight; and the seven colours of the rainbow.

IV.—Of Heat.

Expansion of all bodies by heat; the thermome-

ter; the balloon; origin of winds; melting and boiling; steam; general notice of the structure of locomotives; the vapours of water in the air (clouds, &c.); combustion and coal-gas; heat produced by the rays of the sun, and by friction; the use of conductors and non-conductors of heat.

V.—Of Magnetism.

The direction of the compass-needle; the attractive power of the magnet.

VI.—Of Electricity.

1, *By friction.*

Its origin; conduction by metal, and living animals especially; the spark; thunder and lightning; lightning-conductors.

2, *Galvanism, with electro-magnetism.*

Description of a galvanic battery, and of an electro-magnet; explanations of the electric telegraph, and of electro-typing.

When, as is the case in Natural Philosophy, there is a long-established plan of arrangement, which has been followed by one handbook after another, every attempt to leave the method sanctioned by long usage will necessarily meet with many antagonists, and will need, on the other hand, the kind indulgence of all who approve of abandoning the old system. There is likely to be pecu-

liar difficulty in the new plan, from the circumstance that, although the method abandons all reference to the great philosophical instruments, of which all hand-books on elementary physics speak, just as if they were within every one's reach, yet the teaching of the science is to be founded upon observation and experiment. A person not entering fully into the subject is likely to suppose that by omitting those brilliant experiments, a great number of blanks will result, unless, indeed, we consent to abandon our plan at certain points, in order to admit them; but more mature reflection will impress upon him the conviction that a compact and moderately extensive course may be given with the employment of only simple illustrations.

Together with this alteration of method, care must be taken to present the subject to the pupil in a gradually progressing series, from the easy to the difficult. Hence, the phenomena of weather (being of considerable importance in this course), must be arranged as systematically as possible. Lightning and thunder can only be taken at the end of the course, because they are the most complex of all the phenomena of weather, and because, in order to understand them clearly, a previous knowledge of the origin of winds, clouds, rain, and hail is requisite. The simplest phenomenon is that of clouds or of wind, then follow the doctrines of rain and dew, and lastly, the rainbow. To explain these facts, we must have an acquaintance with many important physical laws, and these

should be so arranged that the explanations in the science of meteorology may follow from them in a natural and easy manner. If we take as granted that the atmospheric and aqueous phenomena are the simplest in their theory, we must have a previous knowledge of the doctrines of heat, as the phenomena referred to depend chiefly on the changing temperature of the atmosphere. This variation of temperature is the subject of daily conversation; but we should still find difficulties in explaining these things, by not having an acquaintance with the laws of gravitation. The origin of wind, the ascent of fire-balloons, &c. lead to the conclusion, that air is lighter when heated than it is when cold. The daily changes of warmth cannot be explained from the different directions in which the sun's rays fall upon the earth, without some preliminary notions respecting the meanings of "vertical" and "horizontal"; plumblines, and the beam of a balance afford the concrete representation of these notions respectively. The positions of these two instruments are the effects of gravitation. Finally, the falling of bodies, being one of the simplest and commonest phenomena, will furnish the basis with which we may commence the course.

As to the *method* pursued in each experiment, we think we have followed that course which the history of Natural Philosophy supplies us with obvious indications of, and which has been the means of bringing the science to its present state of advancement. As long as Natural Phi-

losophy was treated speculatively, its progress was very slow, and it is only since the time of Galileo, who based Natural Philosophy upon observation and experiment, that any rapid improvement has taken place. This is the method recommended by Bacon, from which we cannot deviate without exposing ourselves to the danger of losing the right path altogether. And if a vivid perception of nature can only be obtained along this path, why shall we not lead the beginner over it? Why should we not pursue the same method in teaching the pupil, instead of giving him dissertations in what is considered the orthodox manner? Hence it is, that we have first put forward an experiment; then, as it would be unreasonable to infer a law from a single observation, and as it would be preposterous to seek for additional examples after the enunciation of a law, we have given, in the second place, several analogous occurrences; and then, lastly, have stated the general law gathered from this collection of facts.

With respect to the *apparatus* required in these experiments, it may be necessary to remark, that it is for the most part as simple as the experiments themselves. We also think it of great importance, that the apparatus should not be brought before the pupils fully put together, but that the several parts should be connected with each other in the presence of the pupils. On the other hand, some instruments are mentioned, serving neither for making the fundamental experiments, nor yet capable

of easy construction by an unpractised hand, which are yet so simple in their construction, and so frequently occurring in daily life, that they cannot be dispensed with, or omitted in this course. This observation applies to the balance, the thermometer, the barometer, and the compass-needle.

EXPERIMENTS.

1.—*The Plumbline.*

Take a ball of lead or wood, or of any other material, fasten a string to it, and hold it by the free end of the string. By this simple contrivance, called the Plumbline, in daily use among masons and carpenters, we learn two things:—1st, the direction of the string is always the same, and perpendicular wherever the string is carried; 2nd, the thread is kept stretched by the ball,—if you lift the ball, and then suddenly disengage your hand, the weight will fall as far as the length of the string allows.

Analogies: A stone falling to the ground; drops of rain and flakes of snow from the clouds; the monkey in the pile-driving machine; the weights of a clock, etc.; diagrams and maps are kept stretched by the rollers at the lower end.

From all these phenomena it follows, *that all bodies show a tendency to approach the earth's surface.*

2.—*Weight.*

Put the leaden ball you have just used upon your hand, and you will find, that it exerts a pressure upon it; or, take a sheet of paper, hold it horizontally with both hands, and let some one else put the ball on the middle of the paper; you will find that the ball presses down the middle.

Analogies: A stone pressing into loose ground; a letter-weight; our manner of packing fragile goods, which are never placed under heavier ones.

This pressure, exercised by all bodies upon such as are beneath them, is a consequence of gravitation, and is the

greater, the heavier the body is. The amount of pressure is the weight of the body.

3.—*The Inclined Plane.*

Suppose a book or slate lying on the top of a table, and upon it a leaden ball. The ball does not alter its position, although attracted to the earth by gravitation, for it is supported by the book upon which it presses, because of its weight. As soon as one end of the book is raised so that it comes into an inclined position, the ball runs down, and will descend the quicker, the more nearly the inclined plane approaches the perpendicular. This, too, is owing to gravitation. In the horizontal position the ball only exerted a pressure, and had no tendency to motion; in the inclined position it exerts less pressure on the book, is no longer completely supported by it, and begins to descend.

Analogies: Horses have greater difficulty in pulling a load up a hill, the steeper it is—hence the advantage of winding roads up a mountain; carriers and brewers have a sliding-ladder to facilitate the loading and unloading of their goods.

Law: The steeper an inclined plane is, the quicker a body rolls or slides down it, and the more power is required to raise it up the incline.

4.—*The Equal-armed Lever.*

Nail a small piece of wood, about six inches long and two thick, upright upon a board; or put a book upon a table with its back upwards. Take a ruler, or a stick, uniformly thick and heavy, and try to balance it across the piece of wood. When you have succeeded, you will see, by measuring, that the ruler is supported exactly at its middle point. One side is in equilibrium with the other; gravitation acts with equal force upon each, because they are exactly equal. The chief part of this contrivance is the ruler, which constitutes what is called the

lever, and the point upon which it is supported is called the *fulcrum.*

5.—*Weight and Power on a Lever with Equal Arms.*

The instrument described in the preceding experiment may be used here, with this addition: put two weights of a pound each, one on each end of the ruler used as a lever. The weight on each side of the lever being equal, it will still be in equilibrium. If you remove the weight from one end, and take hold of the ruler at that end, you must evidently use a force equal to the weight just taken away, in order to maintain the equilibrium. The distance from the supported point (or fulcrum) in each direction to the weights, is called an *arm* of the lever; our machine is a lever with two equal arms.

Law: A lever with equal arms is in equilibrium, when the power and weight are equal.

6.—*The Balance.*

The pupils may be shown a common balance; they will soon find out the part which forms a lever with equal arms—the beam. By measuring, these arms may be shown to be exactly equal. The tongue is fastened perpendicular to the beam; both move in the switches by which the instrument is held. The balance will be in equilibrium when the tongue stands exactly within the switches. At the ends of the beam, scales of equal weight are attached. As long as they are both empty they will be in equilibrium, the tongue will be vertical, and the beam horizontal.

7.—*Weights.*

Small weights may be given to the pupils, in order that they may learn to estimate the weight of things, especially of those they are accustomed to use, *e.g.*, a book, a slate, &c. We seldom estimate correctly larger weights; it might not, therefore, be without advantage to let them acquire the power of doing so.

8.—*Loss of Equilibrium.*

A.—Charge both scales of a balance with equal weights; then put into one of them another small weight, or a few shot. This scale will preponderate, and the beam on this side will sink.

B.—Put upon the pillar, used in Experiment 4, a ruler, so that it may assume a horizontal position. Draw the ruler about an inch on one side; it will immediately lose its equilibrium, and fall. The right arm of the lever has become longer than the other, and weighs heavier.

Analogies: We shall lose our equilibrium if we suddenly stretch out an arm when we are standing quite upright; in order to correct the tendency to fall, our body instinctively inclines in the opposite direction. Porters carrying a burden on their backs bend forward; and a nurse carrying a child leans back. The rope-dancer, when he feels himself beginning to fall to one side, stretches out his pole in the opposite direction, and is thus kept in equilibrium.

9.—*The Lever with Unequal Arms.*

In order to find out the proportion between weight and power, or when there is equilibrium on a lever with unequal arms, divide the ruler into three equal parts, and mark the divisions. If you put it upon the pillar used in the former experiments, so that two parts are on one side of the fulcrum, and only one on the other, you will have a lever with unequal arms, the one of which is double the other, and the ruler will not remain in equilibrium. The weight of the lever itself, which may be supposed to act at the middle, will not be supported. Compensate this by a small make-weight on the other side; the lever will thus be brought into equilibrium. Now, if you put a weight of one pound upon the longer arm, and two pounds on the shorter one, the lever will still be in equilibrium. The single pound on the arm of double length, balances the two pounds on the arm of

shorter length. Again, if you make one arm three times as long as the other, you will find the weight of a pound on it will balance three pounds on the shorter.

Analogies: The iron pump-spear is lifted by a handle, which is an unequal armed lever, the shorter arm being attached to the rod within the pump. A pair of scissors cut most easily near the pivot.

Law: The longer one arm is than the other, the less the power required to raise a given weight.

10.—*The Pulley.*

A.—A pulley consists of a wheel, called a sheave, fixed in a block, and turning on pivots; round its circumference is a groove for the passage of a cord. Fasten to both ends of such a cord equal weights, and put it round over a pulley; equilibrium will be found to exist.

Law: The pulley is in equilibrium, if the power and weight are equal.

B.—A fixed pulley, then, gives no advantage in saving power, but only in changing the position in which force may be most conveniently applied. The teacher may illustrate this by pulling the cord in various directions, horizontally, &c., whilst the weight hangs down perpendicularly. Some doors are kept closed by means of a pulley and cord; the perpendicular motion of a weight produces a horizontal movement of the door to be shut. In the pile-driving machine, the workmen pull downwards, whilst the weight rises. Pulleys in ships.

11.—*The Lever with One Arm.*

Crowbars are commonly used for moving heavy weights on the ground. These instruments are evidently levers; they are supported, not about the middle point, but at one end; they have, therefore, only one arm instead of two. How does such a lever act? Take the ruler mentioned in Experiment 4; hold one end of it between two fingers, put a pound weight upon the other

end, and raise the rod with the right hand. The latter has now to raise, not only the weight of the ruler, but also the pound weight. Move the weight nearer to the fulcrum, and you will find that there is less power required to lift the lever.

This experiment, in this form, is only obvious to the performer; it can be made evident to the whole class thus:—Fasten two pieces of wood a few inches long upon a piece of board, drill a hole through the upper part of each, through which a thin piece of wood may easily be placed in a horizontal direction. Fasten to the latter, one end of the ruler, which is to represent the one-armed lever. Near to the other extremity a third piece of wood is fixed upright, rather longer than the others, and having a pulley fixed so as to turn easily at the top. Attach a cord to the free end of the lever, pass it over the pulley, and have a weight tied to the other end of the cord, sufficient to bring the lever into a horizontal position. This horizontal position will not be changed by putting equal weights to the free ends of the lever and of the cord. But if we move the weight upon the lever nearer to the fulcrum, the lever will immediately rise.

Analogies : Where should the weight be placed so as to require the least force to move it? How can crowbars, rudders, &c., be worked with the best advantage?

Law : A one-armed lever requires less force to be exerted, the longer it is and the nearer the weight is to the fulcrum.

12.—*Gravitation and Water.*

Take a cylinder of wood, about a foot long, and an inch and a half diameter; make a channel through it, and put it in a slanting position, like the inclined plane in the third experiment. If you put a ball in the upper part, it will, impelled by gravitation, roll down. But, pour water through the tube, it will flow down and fall to the ground; the last part descends in the form of

drops. By comparing these two experiments, we shall come to the conclusion that the particles of water cohere with less force; the water does not slide down in one compact mass, but it separates, and falls in drops. Further, the water, as it flows down the channel, assumes the form of the latter. Hence, a peculiarity of fluid bodies is, that they assume the forms of the vessels they are put into, and that they separate into parts as they fall.

Analogous Phenomena.—Rain running down from roofs; drops of dew, rain, tears; the fall of rivers; water-mills, &c.

13.—*The Surface of Fluids is Horizontal.*

Pour water into a wide vessel; at first, the fluid is in disturbed motion; but soon the upper particles sink down, impelled by gravitation; the fluid comes to rest, and its surface is *horizontal.* Incline the vessel, and the mass of the water on the side that is higher will sink down, till the surface is again horizontal.

The same observation we make everywhere, both on small and large masses of water; the large ones are said to be *level.* However they may, by winds and storms, be raised at the surface into large billows and waves, they will, when at rest, furnish a proof of the

Law: The surface of a fluid at rest or in equilibrium is horizontal.

14.—*Communicating Vessels.*

Cut a piece of board so as to fit pretty accurately against the sides of a glass vessel, but not quite so high as the vessel itself. Then put the board into the latter so as to stand upright, but without touching the bottom. The vessel is now divided into two parts, from one of which water may flow into the other. Pour water into the vessel; the surface of the fluid will be horizontal in both divisions, and be equally high in each of them. This experiment may be repeated with a glass-tube in the shape of a U.

Analogies: Tea-pots, watering-pots, in which the fluid stands at the same height in the spout and the vessel. Method of leading water from one side of a valley to another.

Law: In communicating vessels fluids maintain their level.

15.—*The Fountain.*

Take a glass tube, about two or three feet long, bent at the lower end, like a barometer-tube; draw it out at this end into a point before a spirit-lamp. Then push out the bottom of a small glass bottle, close its neck by a cork, through which the long end of the tube just passes. The bottle thus forms a sort of funnel, into which water may be poured. It will run through the tube, springing up through the aperture of the shorter leg. It is to be remarked that the water will never rise quite as high as the reservoir is, on account of the gravity of the particles of the fluid, the friction against the glass at the aperture, and the resistance of the air.

16.—*Adhesion between Fluid and Solid Bodies.*

Deviations from the law of fluids in communicating vessels will occur, if the force of adhesion acts as well.

A.—Dip a little stick, previously wetted, into a glass of water. Round the stick the water will stand higher than in other parts of the vessel. Adhesion acts between the water and the wood; the water adheres to the stick, wets it, and is drawn up by it.

B.—Moisten a small piece of board on one side, and place upon it another such piece of board, similarly wetted. If you take up the upper board, the under one will follow, because it adheres. The same may be shown with two pieces of common window-glass.

C.—Pour out water from a glass, inclining the vessel but slightly; the fluid, attracted by the outer part of the vessel, will run down its side instead of falling perpendicularly.

Accordingly, fluid and solid bodies touching each other, are kept close to one another by an attracting force; this is called *adhesion.*

Familiar instances of this adhesion are: writing with ink, painting, printing, glueing, soldering, and gilding.

17.—*Adhesion between Solid Bodies.*

Glue adheres even after it becomes dry and firm; hence it is probable that two solid bodies touching each other may also adhere. To prove this, cut a piece of india-rubber into two pieces, and press them immediately afterwards against each other at the place of section; they will adhere. Care must be taken not to soil the fresh edges with grease of any kind,—not even by contact with the finger. Similarly, a bullet, if smoothly divided, may be made to have its halves adhere to each other, if slightly pressed.

Familiar instances of this experiment are: dust, cleaving to the walls and ceiling of a room; soot on chimneys and cooking utensils; lime; and flour adhering to the clothes of millers, &c.

Applications: Drawing; writing with chalk; the welding of two pieces of iron together.

18.—*Capillary Attraction.*

A.—Take a small glass tube of very fine bore, dip it into water, and the fluid will ascend within it. The inner sides of such a tube—the bore of which hardly exceeds the width of a hair, and hence its name *capillary* exercise an attractive force upon the fluid. The bore being so small, the inner sides support each other, and attract the fluid up with their united force. The fluid rises the higher in the tube, the smaller the bore is. This species of adhesion is called *capillary attraction.*

B.—Wet a small stick, and put it into a vessel of water very close to the side. The fluid rises, as may

easily be observed, in the space between the stick and the inner side of the vessel.

C.—Immerse the lower part of a piece of blotting-paper, or of a lump of sugar, into any fluid. Between the particles of these bodies there are numerous intermediate spaces, or pores, smaller, yet similar to those of a sponge. The inner sides of these bodies, in consequence of their capillary attraction, draw the fluid up until they are completely saturated with it.

Similar Phenomena: A sponge or a towel draws up water; oil ascends in the wick of a lamp; ink in the split of a pen.

19.—*Bodies Floating.*

A.—Put in one scale of a common balance a glass of water, and weights in the other to balance it. Remove the glass, and place a piece of iron—a key, for instance—into the fluid. You will then observe two things: 1st, The key will sink; 2nd. A part of the water will flow out, the key having displaced as much of the fluid as is equal to its own volume. Where the key is now, there was water before, which was supported by the rest of the mass of fluid; if the key were not heavier than the displaced volume of fluid, it would be supported equally well. It is easy to prove that the weight of the key is greater than that of the displaced fluid. If the key were of the same weight as an equal volume of fluid, the vessel with the key would not be heavier than it was before the water was displaced. But if you put the tumbler with the key in it upon the scale, that side of the balance will descend; the key is, consequently, heavier than the volume of water it displaced.

B.—The experiment might be made, in like manner, with a body specifically lighter than water—a piece of wood, for instance, if it could be entirely immersed and kept down. In the meantime it may be arranged in the following manner: Close a small phial with a cork, and

put it upon water; it will float. But how can we find out the volume of water equal to the volume of the bottle? It is evidently a little more than the volume of water which would fill the phial. Weigh the empty bottle, and fill it with water. Double the weights in the scale-pan, and replace the bottle; it will preponderate. Hence the full bottle is more than twice as heavy as when empty. The water in the bottle is, therefore, heavier than the bottle itself; and the latter, full of air, is at any rate lighter than its own volume of fluid. Hence it floats.

Analogies: Oil floats upon water, because lighter; hollow metallic bodies; ships with their freights; life-boats, &c.

Law: A body swims, if lighter than its own volume of fluid.

20.—*Boiling.*

In order to have a clear insight into the process when water boils, it must be heated in a thin glass vessel—a Florence oil flask will answer the purpose. Half fill it with water, and fix it on any convenient stand; put a lighted spirit-lamp underneath. Small bubbles will soon appear, and rise in the water; they consist of air, previously contained in the water. When the water has become considerably hotter, larger bubbles will be seen, commencing at the bottom of the vessel, and ascending like the previous ones; only, at first they will disappear before reaching the surface. These are globules of *steam* (which is water changed into a gaseous state by the heat); but which, while rising, are cooled by the fluid not yet sufficiently heated, and return to the liquid form. But as soon as the whole mass of water becomes hot enough, the number of globules will increase, and rising to the top, put the whole fluid into an undulating motion. This motion of a heated fluid is called *boiling*. The longer this boiling is permitted to last, the more will the

volume of the water decrease, being constantly turned into steam, which, escaping by the mouth of the flask, is dissipated through the air. It will, of course, have been understood that the mouth has been left open during the process. The same process takes place when any other fluid is boiled. Hence may be explained the enriching of broths and gravies by boiling away some of the liquid. The lid of a boiler, which prevents for some time any escape of hot vapour, as also the forming of fresh steam, is useful in economising some of the heat, which would otherwise be lost.

Law: Fluid bodies are changed by heat into vapour.

21.—*Evaporation.*

A.—Pour a few drops of ether into a saucer; in a very short time the liquid will have disappeared; it has been turned into vapour by the ordinary warmth of the air.

Analogies: Water diminishes gradually if exposed to air for a few days in an open vessel; wet linen becomes dry; pools of rain-water in the streets gradually vanish. Vapours require longer time for their formation in this way than by boiling, and occur at the free surface of the fluid only, no bubbles rising as in boiling. The process is called *evaporation.*

Law: Fluids evaporate at common temperatures, that is to say, their upper parts become gradually changed into vapour.

B.—Drop ether on the back of your hand, or moisten your forehead with it; you will have a sensation of cold; warmth is necessary for the evaporation of ether,—which heat must be taken from the hand or forehead.

Analogies: The refreshing coolness after rain; after the watering of streets; after bathing; the catching of cold from damp clothes,—all these, and similar phenomena, lead to the

Law: That cold always accompanies the evaporation of a liquid.

22.—*Mist and Clouds.*

Boil water in a metal or earthenware pot. A part of the water will evaporate. If you look close along the surface of the water, you will not perceive the vapour rising. It is invisible, and transparent, as long as it retains its warmth. Hence it comes about that the air may contain large quantities of vapour originating from the surface of rivers and lakes, without our perceiving it. When the vapour has risen some distance from the surface of the vessel, it will lose some of its warmth, which it gives up to the surrounding air; the vapour then assumes the form of small white clouds, which are composed of minute bubbles of water, not unlike soap-bubbles. In the same way mists and clouds are formed, as also the vapour contained in the breath we expire, which becomes visible in cold weather. Vapour of water rising from every free surface, meets with air colder than itself, becomes cold, and forms mists; but if the vapour is cooled in the higher strata of the air, it becomes clouds. *Mists* are clouds lying on the surface of the earth; clouds are mists in higher strata of the air. The inhabitants of valleys often see the summits of mountains wrapped in clouds, whilst travellers within them appear to be moving in fogs. The fleecy clouds which are at the greatest distance from the earth's surface, and the clouds, called *cumuli* in meteorology, are vapour of water carried up in the morning into colder regions by the rising air; and there they become partially condensed. In the afternoon they sink into warmer regions, give up the shape of clouds, and become again invisible. In the same way the striated clouds, which at sunset exhibit very splendid colours, and rain-clouds, which are blue-black, may be explained.

23.—*Dew.*

Into a perfectly clean glass pour quickly some fresh and very cold water; the vessel suddenly becomes very much cooled. The vapour in the room, most of which

has been formed by exhalation, also becomes cooled, and condenses on the glass, which becomes dim, as we call it. If in winter we take a glass of water out of a cold into a warm room, vapour of water will immediately condense on the sides of the vessel, in the form of dew.

This furnishes an explanation of the condensation of vapour on the windows of a room in cold weather.

When the sky is clear and the air calm, objects on the surface of the earth after sunset become cool, and thus cool the vapours round them. Grass and leaves become the soonest cool, and hence they are the most covered with condensed vapour, or *dew*. When the sky is covered with clouds, they act like a screen, and prevent the heat of the earth from escaping by radiation, so that the formation of dew is wholly or partially prevented. A strong current of wind frequently brings warmer air, which also prevents the formation of dew.

If the objects upon the surface of the earth are so cold that the dew freezes, small particles of ice are formed, and constitute the phenomenon called *hoar-frost*.

Rains, Snow, and Hail.—Rain occurs if the water-globules, of which clouds are composed, are cooled by a strong current of air and condensed into drops, which will fall to the earth on account of their weight. Snow falls if those bubbles freeze; the shape of snow-flakes is that of a regular hexagonal star. Frozen rain-drops form hail, which occurs mostly in summer. How cold can arise at that time of year sufficient to freeze the drops is yet a mystery.* Thus, by evaporation, formation of

* Hail is produced by cold; it occurs only in summer, or in warm climates, and when the sun is above the horizon. It seems to be produced in a humid ascending current of air, greatly cooled by rarefaction, which has an upward velocity, sufficient to sustain the falling hail-stones at the same place till they attain considerable magnitude. The formation of hail is always attended with thunder, or signs of electricity; and it has been found that small districts may be protected from its devastation by the elevation of many thunder rods.—*Graham's Chemistry*. Tr.

clouds, and their condensation to rain, water is constantly circulating at the earth's surface.

24.—*The Rays of the Sun a Source of Warmth.*

Hold your hand against the sun so that the rays fall very obliquely upon it; you feel your hand warmer than before it was exposed, which establishes the heating powers of sun-light. Turn your hand so that the rays fall perpendicularly, greater warmth will be felt.

Analogies: The heat on places so inclined that the sun shines perpendicularly upon them; the melting of snow on roofs exposed to the meridian sun,—whilst it remains unaltered on the fields.

Law: The rays of the sun are the more efficient in heating a body, the more nearly perpendicularly they fall.

EXPLANATION OF THE DAILY AND YEARLY ALTERNATIONS OF WARMTH:—

1. Suppose the top of a table to represent the horizontal plane of our country, and a ball the sun. If you hold the ball on a level with the top of the table, the rays proceeding from it (the rising sun) fall very obliquely, as in the morning. The higher you hold the ball the less oblique will the rays supposed to fall on the table be. For noon the ball takes the highest position, and one most nearly perpendicular; to represent the evening, it is brought down again to the edge of the table.

2. Move the ball over the top of the table, so that its route represents the path the sun describes in summer. This is towards the south, in an oblique direction; it is larger than a semi-circle, and therefore attains a greater height. Then let the ball describe the path of the sun on a winter's day. This is again towards the south, in an oblique direction to the top of the table; but it is much smaller than a semi-circle, and only rises to a small height. If you notice the place where the sun is at noon on these two days, you will easily perceive that the rays

fall more perpendicularly in summer at noon than in winter. Further, in summer the heat of the sun acts for a longer time than in winter.

25.—*The Burning-Glass.*

The pupils may be shown a common burning-glass, and may be made to remark that it is elevated, or convex, on both sides, and will presume that it has a different effect to that produced by window-glass, when light is transmitted. Expose the burning-glass perpendicularly to the sun's rays, and place at a short distance behind a piece of black or brown paper. The rays will pass through the glass, and if the paper is properly held, a bright round spot will be seen, of small size. If the paper is moved gradually to a greater distance from the glass, or nearer and nearer, in each case the spot will enlarge. In the first position, then, the rays of light are brought into the smallest space, or concentrated into a focus; the heat there will also be concentrated, and we shall soon observe the paper begin to smoke, and then to burn.

Analogies: Glass-globes or water-bottles are sometimes exposed to the sun's direct rays, and bodies behind them are consequently much heated, and, if very combustible, may begin to burn.

26.—*The Rectilineal Propagation of Light.*

Fold half a sheet of cartridge paper, or of white card-board, into three parts; the middle one being two inches, and the others five inches wide. Now place the central one as a base upon the table, and bend the other two so that they stand quite upright, and through one of them pierce a hole with a large darning-needle. Light a candle, and hold it near this perpendicular strip; a round and very bright spot will be observed on the other upright strip. The rays of light proceeding from the candle pass through the small aperture, and fall upon the second

strip. If you place a rule upon the hole, and point it in the direction of the candle, the illuminated spot will be seen to be in exactly the same line And if the candle is moved on one side, the illuminated spot will make a corresponding movement, so that, applying the rule in the same manner as before, the spot will be found always in a straight line with the flame and the aperture.

Analogies: Sometimes this is plainly exhibited to us when single pencils of light enter a room full of dust, or one artificially darkened; their path is clearly a straight line. So it is that we do not see the flame of a candle if we interpose a book between it and our eyes, and that we cannot see through a bent tube.

Law: Light is propagated in straight lines.

27.—*The Form and Direction of Shadows.*

A.—Origin of Shadows. Hold a small stick so that the rays of the sun strike upon it, and place a sheet of paper a little distance behind. The paper will be illuminated in all parts, except those in exactly straight lines behind the stick, and we may contrive, by placing the stick pointing to the sun, to have only a small spot. The unilluminated space behind an opaque body is called its *shadow*.

B.—Form of Shadows. Expose a square piece of paper perpendicularly to the sun's rays; the shadow produced will be square too. So the shadow of a round piece will be round. Consequently, shadow resembles in form the body it belongs to. But if you expose the edge of the round piece of paper to the light, the shadow will assume the form of a straight line. The direction of the opaque body will be altered. Hence the form of shadow is influenced both by the form and position of the opaque illuminated body.

C.—The Position of Shadows. If the front of an

opaque body be illuminated, the shadow will lie behind. Suppose the top of a table to be the plane of our country; place upon the middle a book, or some other object that will stand perpendicularly, and let any globe represent the sun. By moving the globe from east to west in an arch, it may be explained how it happens that the shadow of a perpendicular stick falls in the morning towards the west, at noon towards the north, and in the evening towards the east; and thus, how from the position of the shadow, thrown by a tree at different times in the day, the points of the compass may be inferred. This means would not be available on a gloomy day; we may, therefore, congratulate ourselves that we have an unerring instrument, by which we may easily discover the position of the heavens.

28.—*The Mariner's Compass.*

A compass should be provided, and shown to the pupils; they will see that it moves very easily on a pivot, and can be set in oscillation by a very slight draught of air. Yet, the needle may be turned through any angle, and at length regain its former position. From the position of buildings, especially of the church, whose spire is commonly towards the west, it may be shown that the needle always returns to a position pointing northwards, or, more correctly, NNW. Since the needle indicates one quarter of the heavens, it is an easy matter to fix the others. For this purpose draw upon paper a circle with a diameter as long as the needle. Draw two diameters through the circles at right angles to each other, and write at their extremities the initials N, E, S, W. Between each of such two points there are NE, SE, SW, and NW. This drawing is called sometimes the *rose of a compass.* Thus we have the two principal parts of a compass, viz.—the needle and the rose. It only remains now to put the needle on a point in the

middle of the card, and to direct the latter so that the point with the initial N. is to the East (slightly) of the north-end of the needle. The card or rose will then indicate the quarters of the heavens.

29.—*Attraction of a Magnet.*

In addition to the property just described, you will find that the magnet possesses the power of attracting certain bodies. Bring the needle near some small pieces of iron, or filings, and they will be attracted by it, and may thus be raised from the table. Steel or iron is called *magnetic*, if it possesses this property.

30.—*Heat Produced by Friction.*

A.—Strike together a piece of flint and steel; sparks will fly out. The steel was violently struck against the flint; the latter is very hard, so that by continued use the steel is somewhat diminished. Hence the sparks are small particles of steel considerably heated by friction.

B.—A lucifer match will not ignite if rubbed on a polished surface, because there is not sufficient friction; but if moved moderately on the surface of a brick, combustion ensues. It is evident to sight and touch that the surface of the brick is very unequal (rough). The match strikes against the prominent parts, and by the friction heat is produced.

Analogies: Take in your hand a saw or a gimlet immediately after it has been used; you will find it very hot. The wheels of vehicles are smeared, in order to lessen the friction between the wheel and the axle; if they were not, they might soon catch fire, by driving fast, or with a heavy load. Millstones may cause a conflagration, if there is no corn between them while they are in motion. We rub our hands in winter simply to produce heat.

Law: Heat is produced by friction.

31.—*Conductors of Heat.*

A.—A lighted spirit-lamp is placed on a tripod, on which a piece of tin-plate is laid. Then put one extremity of a knitting-needle and of a piece of wood of the same size upon the tin-plate; their other extremities may be supported by a small board. The needle and the wood are equally warmed at the part nearest the plate, for they receive equal supplies of heat. But if you touch the other extremities, the needle will feel the warmer of the two. The heat has travelled from the extremity of the needle to the nearest parts, and has soon diffused over the whole; in the case of the wood, this diffusion, or conduction, does not take place so rapidly. Metal is a *good*, and wood a *bad*, conductor of heat.

B.—Hold in the flame of a spirit-lamp one end of a knitting-needle; it will become red-hot, and you will be obliged to let it fall on account of the heat. Now wrap one end of the needle round several times with paper, or thread, and hold the needle by that end. Because these are bad conductors you will be able to retain your hold of the needle, even when the other end is red-hot.

Analogies: Iron ovens soon become hot; our clothes, because they are bad conductors, retain the warmth of our bodies. Double windows and doors increase the warmth of a room, because the stratum of air between them conducts but slowly; snow, by its warmth, preserves the young seed; and straw protects pumps and trees from frost. In the same manner, wooden handles attached to flat-irons or coffee-pots protect our hands. Glass-vessels for experiments are, when used with a lamp, never placed afterwards upon a plate of metal, but on some non-conducting body, as, *e.g.*, a stratum of sand.

32.—*Expansion of Bodies by Heat.*

Fill a flask with water, and place it upon a stand, on which has been put a piece of tin-plate, covered with sand to the depth of one's finger. Make the water boil

by the spirit-lamp ; before it begins to boil, some water will flow out. Warm water, therefore, requires more space than cold.

B.—Take a moderate-sized bladder, not quite full of air, and fastened at the neck. Hold it above a spirit lamp. The air within will become warm, and distend the bladder. Thus, heat causes air to expand.

Analogies : A red-hot heater may fill entirely the interior of a flat-iron, although it was considerably smaller before it was put into the fire. A wheelwright places the tire of a wheel round the circumference whilst it is red-hot ; the iron contracts as it becomes cold, and is fastened firmly. Glass stopples, which have become fixed in the necks of bottles, may be extracted by warming the necks, either by friction or with warm water, as they thus become somewhat expanded.

Law : Heat expands bodies.

33.—*The Thermometer.*

Examine a thermometer-tube ; it will be found to be entirely closed, but expanded into a bulb at the bottom. Within, is a bright fluid, which is the metal quicksilver. Hold the instrument upright, with the bulb in your hand, and soon the quicksilver will be expanded by the warmth which it takes from the hand ; it will rise higher when more heat is applied. The space in the glass tube is empty ; when the instrument was made, the upper end was open, and the tube was partly filled with quicksilver ; then it was heated till the expanded fluid occupied the whole of the space, and at that moment the top was melted by heat, and hermetically sealed. When the instrument became cool again, the quicksilver contracted, and above it there remained only empty space. If air had been left above in the tube, it would have partially prevented the expansion of the quicksilver, just as a strong wind renders walking more difficult.

The thermometer-tube is commonly attached to a piece of wood, on which a scale is marked. It has been found out—1st, that ice always melts at the same temperature; and 2nd, that water always boils at the same temperature at one level. In order, then, to mark the scale, the bulb of the thermometer is first immersed in melting ice; the quicksilver, on account of the cold, contracts to a certain position, which is carefully marked, and is called the *freezing-point*. Then the thermometer is held upright in the steam arising from boiling water. The point at which the quicksilver then stands is observed, and called the *boiling-point*. The space between these two points is arbitrarily divided in England into one hundred and eighty equal parts, called degrees, and the same degrees are continued above and below the boiling and freezing-points. Thirty-two degrees below the latter is marked as the zero-point; and, consequently, freezing point stands at 32°, and boiling at 212°. All below the zero may be called degrees of cold, but it will be remembered that this point is chosen arbitrarily. In Germany, Reaumur's scale is used, having the space between freezing and boiling divided into only eighty parts, and in France the same space is divided into a hundred degrees; both of them place the zero point at freezing. Our scale was made by a Danish philosopher, named Fahrenheit, and is used also in the United States. Other marks will be found on the scale, indicating certain temperatures, such as *blood-heat*, *summer-heat*, *spirit-boils*, *&c.*

34.—*The Rising of Warm Air.*

To exhibit the movements of air, nothing is more convenient than strips of gold-leaf—such as may be bought in books of a dozen for a few pence. They must be handled carefully to prevent tearing. Cut a sheet into several strips, about two inches long, and rather more

than a quarter of an inch wide, and fasten one end of each to a strip of common paper, so that they may be more conveniently held in the hand. In order to exhibit the upward motion of warm air, hold one of these strips a few inches above the flame of a candle; if it is then brought gradually nearer, it will suddenly fly up, driven by the rising current of air. The same is shown still better above a lamp-glass.

Analogies. A.—If the sun shines upon the floor of a room covered with dust, the heat will soon warm the air, which, rising, carries some of the particles of dust with it.

B.—THE DANCING-SERPENT. The toy known by this name deserves notice here, because it can be easily made by the children themselves. Cut a piece of the size of a crown out of a sheet of writing-paper, and with scissors cut this circle in a spiral manner, so that it consists of several windings, with a small piece left in the middle, by which it may be held. Hold it above the flame of a candle. The current of warm air rising will lift the lower end of the serpent up, but gravity will cause it to descend. These opposite motions take place alternately, and have some resemblance to dancing: whence the name.

C.—THE FIRE-BALLOON. If you make a fire-balloon yourself, it will be desirable to have its diameter at least five feet across. Choose paper of a firm texture, but as thin as possible—such as writing paper—and fasten with paste seven or eight sheets, lengthwise, so as to have a strip about seven feet long. Prepare sixteen of these strips, and when quite dry, cut them into the shape of a lune—that is, broad in the middle, but tapering to points at the ends. Then fasten horizontally at some distance from the ground a small circle of paste-board, to which attach the ends of all the strips with paste, so as to occupy the whole circle of paste-board, the paste also being used to connect the several strips lengthwise

to each other. The lower extremities are fastened round a circle of willow-wood or cane, from which wires descend and support a small tin cup. Into the latter naptha or spirit is placed, and lighted. The air soon gets warm, and expands, and carries the balloon up.

35.—*Draught and Wind.*

Open the door between a heated room and a colder one. You will soon feel a draught of cold air on your feet. The air in the room was warmer; the cold air must, therefore, have come out of the other room by the lower part of the door. Hold a burning candle or a piece of gold-leaf at the lower part of the opened door, it will be blown into the heated room—a proof that the cold really pours in by that part of the door. Now hold the piece of gold-leaf at the top of the doorway, where the air is warmer; it will be blown outward. Hence there must be at the top a draught of warmer air blowing outward.

Analogies: If you come out of the sun into shadow, you feel a draught of air; chimneys; the draught in a conflagration.

Law: The warmer air rises upwards, and colder air takes its place.

THE WINDS.—This rushing of cold air towards warmer parts of the earth, takes place continually on a large scale. The air upon a hot region of the earth must rise, and other draughts of air replace it close upon the surface of the earth.

The air is therefore in a continual motion; its currents are called *winds.* They arise commonly through some part or other of the earth's surface, being warmed more than others. This is very regularly indicated by the winds blowing on sea-coasts, for the day-time wind blows from sea towards the land, because the latter is sooner warmed by the rays of the sun; after sunset the water retains its warmth longer; the wind blows then from the land toward the sea.

A violent wind is heard especially if it breaks upon solid bodies; the motion of the air is attended by a roaring, originating in the same manner as sound in general.

36.—*The Origin of Sound.*

Take a violin, and make its deepest chord sound by striking it with the finger. If you look at it a little attentively, you will perceive the chord move to and fro with regularity. This trembling motion of the chord is still more observable, if it is stretched a little tighter. These regular motions of the chord, by which its sound is produced, are called vibrations. Press upon the chord with one finger for a moment only; it will return to its former position, because of its being elastic, very much like a spring,

With the aid of an accordion it may be shown that sound is produced also by the oscillation of elastic steel-plates. And with a key, whistle, or any brass instrument it can be easily proved that the air too can be put into audible vibration if it impinge upon solid bodies.

In short, sound is produced by the oscillations of air, or elastic bodies in general. These oscillations produced at some place or other are imparted to the air, and strike our ear just as the waves produced by a stone thrown into water, dash upon the shore.

ECHO.—An elastic ball rebounds from the wall against which it is thrown; and the waves of water are thrown back from the solid banks, and return to the place were they originated. Very much in the same way oscillations that produce sound, if they strike upon solid, impenetrable bodies, are, to a great extent, reflected by the bodies struck upon. If a wall, a forest, or a mouutain, is so far distant that the sound of words uttered is reflected in that direction only after the sound of the uttered words themselves had already died away, the sound thus reflected is called an *echo.* The echoes of the round

"Kœnigs platz," in Cassel, and of the Loreleifels on the Rhine are celebrated; the latter repeats a sound 17 times.

37.—*A Lamp Shade and Twilight.*

Light a solar-lamp, but do not put on the shade. If you look at the space around the foot of the lamp, you will find it pretty dark, because very few rays of the flame of the lamp fall upon this space. Put the shade upon the lamp, the space around its foot will be particularly illuminated. Evidently rays of light fall now into this space, that before took another direction. This change is owing to the shade; the rays which proceed from the flame in all directions, fall now upon the shade, and are reflected by it like an elastic ball, or like sound when it forms an echo, not towards the direction of the flame, but below.

In carriage-lamps there is generally a piece of metal, called a reflector, behind the flame, by which the intensity of the light is considerably increased, throwing along the road the rays falling upon it. This reflector is purposely kept polished, for the more polished the surfaces of bodies are, the better reflectors do they become.

TWILIGHT.—The air fulfils the same office on a large scale, that the lamp-shade does. When the sun sets, and is no longer able to send its rays directly, yet some of them will reach the strata of air in the west, from which they are reflected to us. Hence the twilight after sunset. But when the sun illuminates the strata of the east, before it rises, these reflect the rays falling upon them, and produce the dawn, or morning twilight, which forms the transition from the darkness to the light of day.

38.—*The Plane Mirror.*

Show the pupils a common looking-glass, open the back and exhibit the metallic coating, which consists of tin-foil and quick-silver. This sheet could not be made smooth and brilliant enough to reflect without the glass. Nor would the glass be sufficient by itself; for it would permit

the greater number of rays to pass through. The union of both constitute the mirror—the opaque substance and the glass. This may be shown by taking a piece of common glass, and holding it over an oil-lamp; it will be covered on one side with lamp-black, and represent in in some measure a looking-glass. The panes of glass doors reflect our image, if we put curtains behind them; the principal phenomenon exhibited by the mirror is, that it reflects the rays of light exactly in the order in which they fall upon it. Hold any object before the mirror, its image will be seen exactly the same distance behind the glass, and of the same size and positiona; river reflects the trees, &c. on the banks.

39.—*Refraction of Light.*

A.—Fill a large tumbler with water, and hold a pencil in an oblique position in the water. It will appear as if it were broken at the surface of the water. We see the pencil because it sends rays of light to our eyes. These rays now pass not only through the air, but also through the water, and as soon as they pass from one of these transparent media to the other they change their course.

B.—Put a coin into a basin, and stand so that the coin may just be hidden by the edge; let some one else pour water into the vessel, the coin will immediately appear, without your eye having changed its position. The rays of light proceeding from the coin take a different course now, and one which forms a broken line.

Analogies: Clear water appears to us to be less deep than it really is, because the ground appears more elevated by refraction of light; for the same reason fish in water appear higher than they really are.

40.—*Spectacles with Convex Glasses.*

A.—Just as the course of light is altered in passing from water into air, so it is changed in passing through glass, as, for instance—convex glasses. Hence objects seen through them appear different. In order to observe the most important facts connected with this, take a convex spectacle glass, or a burning-glass, and light a candle so as to have an object from which proceeds many rays of light, and which is consequently seen very distinctly. Close one eye, hold the glass before the other, and bring the candle within a few inches; you will see the light in the same upright position, but magnified. Hence convex glasses are used as *magnifying* glasses.

B.—But we have lost sight of one circumstance—the light is seen magnified, but is it seen in the same place that it really stands in, or do the rays of light take such a course that we think we see the candle in some other place, as we did the coin in Experiment 39? In order to find this out, close one eye again; hold the burning-glass close before the other, and look at the candle with the lens as near to it as possible. Then move the burning-glass quickly aside, so that the light is seen with the naked eye, and you observe that the light stands really nearer to the eye than it appeared when seen through the glass. Hence objects appear not only to be *magnified,* but also at a *greater distance from* the eye, when viewed through a convex glass.

C.—People who live much in the open air, and are accustomed to look much at distant objects, have great difficulty in clearly distinguishing objects near them. More than that, the fluid in the eye diminishes in advanced age with most men; they begin to hold objects at a very great distance from the eye, and are in the evening scarcely able to read, except by holding the candle between the book and themselves. Their eyes have become *long-sighted,* and can only see distant objects dis-

tinctly. Convex spectacles, having the property of increasing the apparent distance of objects, are thus adapted to correct this infirmity.

41.—*Concave Spectacles.*

A.—Take a concave spectacle-glass, such as is worn by near-sighted people. Close one eye, and look with the other through such a glass at a lighted candle some feet off. The rays proceeding from the candle are so refracted, that the light appears to be smaller than it really is; but it is seen very distinctly. But does it seem to stand nearer to, or farther from us, if we look at it through the glass? To find this out, proceed in the manner described in the preceding experiment (40th, *B*). You will then easily perceive that the candle is really at a greater distance from us than it seems to be through the glass. In fact, objects seem to be nearer if seen through concave glasses.

B.—Some men are able to see distinctly only such objects as are at a short distance from their eyes; they are *near-sighted.* Concave glasses bring distant objects nearer to the eye; hence concave glasses are best suited for near-sighted people. But, if the glass were too concave, or, as the phrase runs—too strong, it would bring the objects too near to the eye, and accustom it to see from a distance still less than it used to do, and, thus, the near-sightedness would only be increased. Great attention is, therefore, necessary in choosing spectacles; also the wearing of spectacles will prove detrimental to a healthy eye; and therefore, lastly, spectacles to preserve the sight are an imposition. Opticians distinguish the degree of strength of spectacles by numbers; the smaller the number, the stronger the glass.

42.—*The Peep-Show.*

Show the pupils a peep-show of ordinary construction. Draw their attention first to the picture, produced by

the landscapes, &c. upon the mirror on the upper oblique part of the box. For this purpose take one of the drawings, put it upon the table so as to lie in a direction opposite the spectator. Hold above it a looking-glass, exactly in the same oblique direction in which the mirror is fixed in the peep-show. The drawing will be seen in the looking-glass in the upright direction. Secondly, point out the convex glass in front of the box, through which the image in the looking-glass is magnified, and appears to be more distant. See Experiment 40.

43.—*Inverted Pictures in a Dark Room.* *(The Camera obscura.)**

Make a box of paste-board, about four inches broad and high, and six inches long. Let the box be open at one end, through which a smaller box may be slid, like the tubes of a telescope. This smaller box is also open at one end; its front must be made of thin, white tissue paper, or oiled letter paper. Make a hole as large as a pin's head, in the front end of the larger box.

Rays of light proceeding from objects before this hole, will enter through it, and fall upon the paper. But the four sides of the smaller box, obstructing the passage of all rays proceeding from other parts; no rays fall upon the paper, but such as enter through the opening. Hold the box with its front towards the daylight; all clearly illuminated objects will be represented upon the transparent paper of the smaller box, which for this purpose can easily be put into a proper position, by sliding it backward and forward. All objects, (especially windows,) shone upon by the sun, will be seen upon the paper, with their natural colours—only the picture is inverted.

From this fact we may infer that *all objects reflect white or coloured rays of light, and thus become visible to us.*

* Compare Experiment 45.

But how does it come to pass that the pictures are inverted? Put a burning candle before the aperture of the front-side. From the top of the flame rays proceed through the aperture downward, and reach the transparent paper at a lower place; on the other hand, the rays from the lower part of the flame travel through the aperture in an oblique direction upwards. Hence the candle will be copied inverted, because the rays proceeding from it cross each other.

44.—*Small inverted Images through Convex Glasses.*

Suppose a convex glass, put into the aperture of the box just described. What would be the result? From the 25th Experiment we know that a convex glass concentrates the rays, or brings them nearer to each other. The boundaries of objects appear, therefore, to be nearer to each other, and pictures become smaller. Light a candle, and take a sheet of white paper in the left hand to serve as a screen to receive the picture on; hold in the other the burning-glass or convex spectacle-glass. Let the glass be a few feet from the candle, and at first near to the paper a bright circle will be seen upon the latter. Move the glass further from the paper—the flame of the light will appear upon it inverted and small.

If you hold the glass at some distance from the eye, towards objects not too near, it will be found that they appear, when so viewed, to be inverted and smaller.

45.—*The Camera obscura and Photography.*

Make a cubical box of paste-board, about four inches in every direction. Make one side not of paste-board but of ground-glass. In the front make a round hole, so as to admit a cylinder with a convex glass. To protect the back against the rays of light, fasten to it a sheet of paper to act as a curtain. The moveable cylinder with

the convex glass being put near enough to the transparent back, trees, buildings, and men opposite the front will be represented on the paper, but inverted, and on a smaller scale. This machine, here described in its simplest form, is called a *Camera obscura.*

PHOTOGRAPHS.—The pictures produced by the camera obscura are very neat and distinct. It was, therefore, very desirable to fix and preserve them in some way or other. It was known that the light of the sun can change the colours of a body. It was now only necessary to find some substance which might be changed by light in the shortest time possible.

A Frenchman, named Daguerre, discovered such a substance, and became thus the discoverer of Photographs, or Daguerrotypes. He took a copper-plate, coated with silver, and put it, after carefully cleaning it, upon a porcelain cup containing iodine dissolved in water. From this solution vapours rise, and adhere to the silvered plate, giving a yellowish or voilet-bluish hue.

Now take the camera obscura, remove the oiled paper, and put in its stead the plate covered with iodine-vapours. The picture falls upon it, in its brighter parts the iodine is removed by the stronger light; for which proceeding only a few minutes are required. Take the plate out of the camera obscura, no picture is as yet to be seen. Put it, therefore, upon a tin plate, heated a little, and coated with quicksilver. Small globules of the latter will adhere to the bright places of the picture, viz.—where the silver has been affected by the rays of light—and the picture is now distinctly produced. To protect the iodine from undergoing any further changes by light, the plate is immersed into boiling salt-water, which dissolves and removes any iodine still attached to the silver.

Hence silver forms the shade of every photograph, whereas the lighter places on it are formed by quick-

silver, fixed upon those spots from which light has removed the coating of iodine.

46.—*The Astronomical Telescope.*

Distant objects seen through a convex glass appear inverted and smaller. (See Experiment 44.)

We know from Experiment 40 that near objects appear magnified if seen through a convex glass.

We could magnify by such glasses not only objects themselves, but the picture produced by them, and which we could also catch upon paper.

Having obtained an inverted distinct picture through the first convex glass, hold another glass of the same kind behind the first, as if you would view and magnify the picture of the first through the second. The picture of the distant object will continue to appear inverted yet near, distinct and magnified. Hence we may compose a telescope of two convex glasses, for which purpose the glasses are commonly put into cylinders. Astronomers make use of such telescopes, since an inverted image of a star is of no consequence. Telescopes for viewing objects on earth contain commonly more glasses for the purpose of inverting again the inverted picture.

47.—*The Colours of the Rainbow.*

Expose a water bottle, when filled, to the rays of the sun; the white light of the latter will be refracted in passing the water; and connected with this refraction is another phenomenon. Hold a sheet of paper at some distance behind the bottle which is a little inclined, and the colours of the rainbow, chiefly the red and violet, will be seen upon it. Hence the white light of the sun has, by refraction, been analyzed into the colours of the rainbow. Put the paper upon the wall, below the window through which the rays of the sun enter, the water bottle can be turned so that the rays of the sun, falling upon

and refracted in it, are reflected by the water and fall upon the paper. We can then see upon the paper coloured bows, in which the colours of the rainbow are distinctly visible.

THE RAINBOW.—We observe a rainbow if we have the sun behind, and a rain cloud straight before us. The light of the sun falls upon the rain-drops, is refracted in them, and divided into seven colours, viz:—red, orange, yellow, green, blue, indigo, and violet.

48.—*Elasticity of the Air, and the Diving-Bell.*

A.—Fill a bladder with air, by blowing into it until it is quite distended, and then tie it up. Push against it with a finger; the air within will be compressed. Remove the finger; the bladder will be again distended by the air, very much like a compressed spring which rebounds as soon as the pressure ceases. The compressed air extends itself again, and occupies as much room as it did at first—hence it has the property of compressibility and extensibility.

B.—Immerse a drinking-glass, turned upside down, into a deep vessel filled with water. If you press the glass down in a perpendicular direction, the water will enter it, and compress the air contained in the glass. Press the glass still further down, so as to be below the surface of the water, the latter will still continue to enter the vessel, but it will never fill it; on the contrary, there will always remain some air in the upper part of the glass. But where there is air, there is no room for water. The air in the glass is, moreover, compressed, and has a tendency to expand itself. Withdraw your hand suddenly from the glass, it will spring up with much energy.

C.—As some air remains in the upper part of the inverted glass, and cannot be displaced by the water, so some air will remain in the upper part of a box open at

and men will be able to live in it for a short time. Diving-bells formerly had the shape of a large church-bell; now that of a square box about five feet high. They are manufactured of cast-iron; the upper side has several holes with strong glass in them to admit light. Small benches for the divers to sit upon are fixed in the interior of the bell. The whole machine is fastened to a scaffold by strong chains, and is let up and down in the sea by means of pulleys, &c.

49.—*The Pop-Gun and Pea-Shooter.*

A.—Take a common pop-gun, such as boys use to play with. Close both ends with stoppers, which are commonly made of raw potato or of tow. If you push one stopper by means of a stick, the air between the two ends of the pop-gun will be compressed—it has a tendency to expand again; but as yet its power is not strong enough to force the other stopper out of the cylinder. But move it further on, and thus compress the air more, and the stopper will issue from the gun with a loud noise.

B.—The pea-shooter is a tube of wood some feet long, and very carefully bored; or it is made of sheet-tin, rolled into a cylinder. Put a bolt in it. By blowing into the tube it becomes filled with air, which is now compressed; the bolt will move on a little. By blowing still harder, and thus increasing the pressure upon the air, its power of expanding is increased too—in fact, the bolt will be forced out of the tube. The harder you blow the farther the bolt will fly.

Law: Air tends to expand with greater force the more it is compressed.

50.—*The Air-Vessel in Fire Syringes; or, Hero's Ball.*

To make a jet, by which the water is made to rise by the action of compressed air, close a bottle with a cork

hermetically. Bore a hole straight through the cork, so as to admit putting through it a piece of clay-pipe, or a glass-tube, which must, however, be a little longer than the bottle. After having done so, half fill the bottle with water, close it with the cork, and put the tube through, so as to reach almost the bottom of the bottle. The bottle contains air above, and water below. If by blowing into it through the tube, you drive more air into it, the air will rise in small bubbles, and collect above the water. The air will here, of course, be compressed; it will expand, when the pressure is removed, press upon the water, and cause a jet of it to rise through the tube. If the tube did not reach down to the water, the air blown through it would come out of it again by the same way as soon as you ceased blowing.

The machine here described takes its name of *Hero's Ball*, from the ancient mathematician, Hero of Alexandria, and is quite the same as the *air-vessel*, *i. e.*, that vessel in fire syringes that keeps the water rising.

51.—*The Pressure of Air.*

A.—Fill a large tumbler with water, and immerse in it a glass tube of small bore, open at both ends, and not longer than the glass is deep. It will become full of water, and on taking it out, the water will flow out, being drawn down by gravity. Immerse the tube completely in the water a second time, and close the upper end whilst below the water with your finger, and remove the tube in this position; the water will not flow out, but on the contrary, will remain in the tube. How does this happen? The tube contains no air, but it is surrounded on all sides by the atmosphere, which extends upwards for several miles; the lower part is compressed by the upper, and presses against all bodies. Thus it presses against the lower aperture of the tube, and supports the water. Remove your finger from the

top, and the water will immediately flow out, for the air presses now equally at the upper and lower end, and gravity causes the water to fall.

B.—Put a key or thimble to your mouth, and withdraw the air; it will adhere to the lips. The surrounding air presses it against them. If there were any air in the key, it would press with the same force from the lip that the surrounding air presses against it.

Analogies:—1. Take a small glass and fill it with water; then put upon it a smooth piece of paper, and, putting your hand on the top, invert the glass quickly. Remove your hand, and the water will still be supported by the air. 2. No beer will flow out of a full cask whose vent-hole is closed, even if the tap is opened, because the pressure of the air keeps the fluid back. 3. When we inhale air, we enlarge the cavity of the breast and lungs; hence the air in them will be rarefled, and the external air is forced in by the pressure to which it is subjected; and when we exhale, we contract the cavity, and thus force out a portion of air. 4. In smoking, similarly, suction causes a current of air through the pipe.

52.—*The Barometer.*

Show the pupils a barometer—known to most as a weather-glass. The instrument consists of a glass-tube, closed at the top, and turned up and expanded into a bulb at the lower end. By measuring it you can show that it is about thirty-four inches long. The quicksilver in it is already known to them by Experiment 33. We have seen that a fluid will stand equally high in all communicating vessels; why, then, does not the quicksilver run out of the bulb? The answer is easy, if you consider that in ordinary communicating vessels the air rests equally on all of them; in the barometer this is different.

Upon the open bulb the whole weight of air presses, whilst in the tube there is only quicksilver. The tube is originally gradually filled with the mercury, and then boiled in order to get rid of all air. The column of air outside is as heavy as that of the mercury in the long part of the tube, and maintains equilibrium. If the pressure of the air increases, the quicksilver rises, and if the pressure diminishes, the quicksilver falls. To be able to observe correctly this rising and falling, the tube is graduated into inches, beginning with the level of the mercury in the bulb. The inches from 28-31 are also divided into parts, and the mean height is about thirty inches.

The Barometer as a Weather-glass.—East winds generally cause the barometer to rise; they come over large tracts of land, and bring dry air; the weather is generally fine if the barometer rises. South-west winds cause the barometer to fall, and as they come over the Atlantic, they bring air saturated with moisture. Hence rain generally accompanies a fall of the barometer. But as the barometer only shows the increase or decrease of the pressure of the air, and the weather depends on other circumstances as well, this instrument is not to be implicitly depended on as a weather-glass.

53.—*Bellows and Valve.*

As a knowledge of valves is necessary in explaining pumps and fire-engines, the teacher may show the pupils a common pair of bellows, which have an aperture on one side, under which is a valve, opening and closing. If you draw the bellows open, the air within will be rarified, and the external air will pass against the valve, which opens, and thus the bellows become full of air. Close the bellows; the air contained presses against the valve, but it cannot open it in that direction; hence the air can only escape by the nozzle.

54.—*The Suction Pump.*

Take a piece of elder wood, such as boys use for pop-guns, or, better, a glass tube with a large bore; then take a long piece of wood, and tie round it some tow, sufficient to fit the tube accurately, like a piston. Put the lower end of the tube into water, and draw the piston up; as no air can come beneath the piston, there will only be an external pressure of the air on the water, and consequently the water will be forced into the tube. The chief part of a *pump* consists of a long tube like this, reaching down to the water, and containing a piston within it fitting tight. The piston is fixed to an iron piston-rod, moved up and down by the pump-handle, which acts as a lever. When the piston is raised, the water below will evidently ascend. If the piston were made exactly like the one just described, when it is withdrawn from the top of the tube, the water would immediately sink again. Consequently it has a bore, to which is attached a valve, opening only upwards. When the piston is forced down, the water raises the valve and passes through, and then, on lifting the piston up a second time, the water is drawn up with it, and flows out by the spout. Lastly, to prevent the water falling out of the tube, it has at its lower end a second valve opening upwards.

55.—*The Fire Engine.*

If there is any opportunity of examining a fire-engine, it would be advisable to do so; if not, a model made of glass would answer the purpose, or at all events a diagram. It consists of a large square box resting on four wheels; above it there is a two-armed lever with handles; two iron rods are attached to the lever, and each of these is connected with a solid piston fitting into a cylinder. These cylinders have a valve at the bottom opening only upwards, so that, when the piston is drawn up, the water enters, but at the same time is obliged to seek another

exit, when the piston is pressed down; that is to say, the pistons themselves contain no valves. This exit is found in the side of the cylinders through a tube, which leads into an air-tight box called the *wind-box*. In the connecting tube there is another valve opening only into this box. Consequently, when a quantity of water has been driven into the air box, it compresses the air in it into a smaller space; which by means of its elasticity endeavours to displace the water, and drives it out of a pipe connected with the hose. By this means a continuous stream of water is forced out of the wind-box, which is itself constantly replenished from the cylinder.

56.—*Fire caused by mixing heterogeneous Substances.*

A.—Pour a little water upon a piece of burnt lime in a saucer; the lime will expand, and become considerably heated. A high degree of heat being produced, great caution is required in slackening lime.

B.—Take a lucifer-match, and dip it into concentrated sulphuric acid; it will be immediately ignited.

Analogies: All vegetable stuffs lying in heaps—as corn, flax, hay, even damp flour—become very hot. Stuffs recently varnished often ignite, if packed close together; and coals in powder will occasionally do the same.

57.—*Fire extinguished.*

A.—Put a short piece of lighted candle on the table; then put over it a common lamp-glass, so as to prevent air from coming beneath it to the flame. If the cylinder is not quite level, put the candle first on a thick stratum of sand, and press the cylinder down so as to obstruct the air—the candle will soon be extinguished; hence a draught or a current of air is requisite for combustion. The flame is extinguished as soon as air is prevented from reaching it. Hence burning fat may be extinguished by covering it, and burning buildings by pulling them down.

Bnrning chimneys are stopped up with damp sods at the top.

B.—Put a lighted spirit-lamp under a tripod, on which rests a piece of tin, covered with a thick layer of sand. Put some matches on the sand, they will soon be heated, but by no means begin to burn until a thermometer, put upon the hot sand, indicates a heat of about 140 degrees.

The second requisite for combustion, then, is a considerable degree of heat. If therefore, you cool a burning body, the flame will be extinguished. If a fire is put out with water, both means are used. In the first place cold is produced by the evaporation of the water, and second, the vapors thus produced, prevent the air reaching the burning body.

58.—*Coal Gas.*

Take a small glass bottle, or a test tube about six inches high ; half fill it with fine shavings of wood, and close the mouth with a cork. The cork must have a bore, through which is put a thin glass-tube a few inches long, (or a small piece of the tube of a clay-pipe) so that it descends partially into the bottle. Hold the glass inclined above a spirit-lamp. A gas will be formed within the glass, and rising through the tube, cause an unpleasant smell. If you bring a light near it, the gas will ignite—at last, there is only left charcoal in the glass. Hence we obtain by heating wood, an element which seems like common air, but is distinguished from it by its inflammability. All sorts of air are called gases.

This is the same sort of gas as that obtained in gas-houses, by heating coals in large iron retorts.

59.—*Flame.*

Take two lighted candles, and when they have made a pretty long snuff, blow out one, and you will perceive a vaporous matter rising from the wick. This gas is

similar to that produced in Exp. 58. In order to examine it, bring the burning candle above the snuff, the gas rising will be immediately ignited, and the candle begins to burn again. *Flame consists of gases in combustion.* Bodies, which can be easily turned into gas by heat, burn with a flame, the rest only *glow*. Light is produced from an oil-lamp by the heat, first turning the oil into vapour, and then igniting this vapour.

60.—*Flame in the Solar-Lamp.*

If you examine the flame of a candle, you will observe in the middle a dark cone. Put a lucifer match into this quickly, it will not ignite so rapidly as when held on the outside of the flame. A thin iron wire will become hot sooner at the exterior than in the inner part. The dark cone consists of carburetted hydrogen, produced from the materials of the oil by heat; but it does not burn, because the air has no access. This gas burns with a bright flame only where there is free access of air.

B.—If air could have access to the interior, the gas would also burn there, the dark cone would vanish, and we shonld have a brighter light produced than our lamps give. To be convinced of this, light a lamp with a round burner (an Argand lamp); take notice of the double set of air holes. One set allows the air to rise, so that it has access to the flame; the other admits air into the interior of the flame, through the hollow reservoir. Such a lamp, therefore, burns brighter, because it has a double draught of air.

61.—*Oxygen.*

Take a funnel, or as a substitute, a phial with the bottom knocked out; fill it with fresh leaves of any plant, and place it inverted in a tumbler full of water. The water must be sufficient to cover the funnel entirely.

Now close the small end of the funnel with a cork, and pour out a little of the water. Place the whole in the sunshine, and speedily bubbles of gas will be seen rising from the leaves to the upper part of the funnel. If the water, in consequence of this generation of gas, has become depressed in the funnel, so that it stands at the same height within and without, take out the cork, and hold immediately a lighted splinter of wood above the funnel. It will burn brilliantly and be consumed. The gas in the funnel unites eagerly with the burning wood, and it is consumed. Because this gaseous body forms in combination with several others, acid compounds, it is called *Oxygèn* (Greek *δξυς* and *γενναω* Iδ;) ;*e.g.*, with sulphur it forms sulphuric acid. All ordinary combustion is the union of oxygen with a combustible body. This oxygen is contained in the air. Plants in the sunshine exhale it, as our experiment shows. Water was required to collect the oxygen, for otherwise it would have mixed with the surrounding air, as it commonly does. You may obtain more speedily a larger quantity of oxygen from the leaves of plants, if seltzer-water is used, since it contains more carbonic acid than common water.

62.—*Nitrogen or Azote.*

Our atmospheric air is composed of two different gases; one of them is oxygen, which we have already become acquainted with. What is the other? Since oxygen combines with a burning body, we have only to exhaust it by burning the oxygen from a portion of air inclosed in a vessel. For this purpose fasten a piece of wadding, or sponge, on the end of a wire, and dip it in naphtha or spirits of wine; prepare a vessel full of water, and bend the wire so that you may put an inch or two into the water, whilst the sponge is above it. Ignite the sponge, and hold an empty tumbler over it, so that the rim of the glass is just immersed in the water. The light-

will be extinguished as soon as the oxygen is exhausted, and water will rise in the tumbler about a fifth of the way up. The gas left in the tumbler which occupies the other four parts is called *Nitrogen,* and sometimes *Azote* because animal life cannot be supported in it. A lighted paper will be extinguished in this gas. It is to be remarked that neither life nor ordinary combustion can be maintained without oxygen.

Our atmospheric air, then, is composed of one part of oxygen, and four parts of nitrogen.

63.—*Steam and the Locomotive.*

Wrap some tow round a piece of wood, so as to make a piston (See Experiment 58), fitting accurately into a strong test-tube. Fill the tube about half way with water, and make the water boil over a spirit-lamp. Steam will arise, and gradually displace all the air from the glass. When this appears to have taken place, remove the tube from the lamp, immediately push in the piston, and as the water cools, press it down till it reaches the surface of the water. Now heat the water a second time, and the steam generated will drive up the piston.

THE LOCOMOTIVE.—Just as this motion of the piston in the tube is occasioned by the force of steam, so on a large scale in a locomotive are pistons moved backward and forward in two horizontal cast-iron cylinders, which are placed, one on each side, close to the wheels of the locomotive. By means of a peculiar contrivance, steam is first admitted on one side of the piston, and drives it forward, then by a change in the position of the contrivance, steam is admitted to the other side of the piston, whilst at the same time an opening is uncovered, by which the previous portion of steam may escape after having performed its duty. In like manner the second portion of steam is sent out of the cylinder through a similar

opening, when steam is admitted to the side of the piston where it was at first; and this takes place alternately. The puffing noise in a steam-engine is produced by the successive portions of steam escaping from the cylinder, and the draught of air through the furnace is increased in stationary engines by the increased height of the chimney. The piston-rods are in connection with the axle of the large driving-wheels, and so set the machine in motion.

The cylindrical part of a locomotive, from the chimney to the furnace, is the boiler; it contains water, through which pass from the fire-place to the chimney more than a hundred metal tubes, through which the flame rushes; this is for the purpose of producing steam more quickly and copiously. The steam collects above the water, and is passed into the cylinders through tubes. Locomotives generally have safety-valves, opening only outwards, so that when the force of the steam is too great, it presses them open, and part of it escapes; or they are opened by the engine-driver, when the machine is not to be further used.

64.—*The Telegraphic Wire and the Simple Galvanic Cell.*

The wheels of a locomotive and of railway carriages run on rails, so that they make no ruts by sinking in the ground; they, evidently, have less friction to overcome and run more easily.

In addition we may notice on most railways, a wire, stretched between high poles and running from station to station. This extent of wire belongs to the electric telegraph; it is the path for electricity, just as the rails are for the carriages.

To explain this a little at length, it is well known that galvanic electricity is produced, amongst other ways, by the contact of two metals. To show this by a simple experiment, such as this book only admits of, is very

difficult. However, that some effect is produced by such contact may be exhibited in the following manner: Place a sixpence and a piece of copper, one above, and the other below the tongue, and touching one another, and a slightly acid taste will be perceptible. But Volta's fundamental experiment, which proves that electricity is produced by the contact of a copper and zinc-plate, requires at least the use of a condenser, or even of Bohnenberger's electrometer, which consists of a sheet of gold leaf between the two poles of a dry, or Zamboni's pile. To perform this somewhat doubtful experiment in the school is not to be thought of. Besides, in our common galvanic cells, electricity is not generated by the contact of two metals only, but by *two metals, or by one metal and charcoal, together with fluids*, and it has been established by experiments that a single metal and a fluid will produce electricity. But as these experiments are somewhat refined, we take the simple galvanic cell for granted, without inquiring into the theory, considering this plan most advisable in an elementary work.

What kind of galvanic cell shall we choose out of a great number of various constructions? In the first place, all galvanic cells, however different they may be in the detail, have something in common; they consist of *two separated spaces or vessels*. One vessel may be a common tumbler, into which the second is placed, which must be not higher than the tumbler, but considerably narrower, so that two fingers may be put between it and the side of the tumbler. The second vessel must be composed of some porous material, which allows water to pass through; it may be made of the red clay of which flower-pots are made; a small flower-pot itself might serve the purpose, if the hole at the bottom were stopped up. Or it might be made of porous pipe-clay, and could be purchased for a few pence. Lastly, it might be made of common unglazed pasteboard, or strong packing-

paper; for this purpose cut a piece of pasteboard not quite so high as the tumbler, and roll it into a cylinder of the dimensions mentioned above; where the edges meet, fasten with sealing-wax, and also fasten a wooden bottom to the cylinder with sealing-wax. With these preparations several different cells might be made with the use of different metals in pairs.

The oldest (constant) galvanic cell, which is still in use in the electric telegraph-office, consists of the metals copper and zinc. To construct such a cell, procure a strip of zinc from a brazier, at least as thick as the sheet-zinc used to cover roofs of buildings, and a little longer than the depth of the porous inner vessel. Roll the zinc into a cylinder that will fit easily into the porous cell, and solder a copper-wire, about twelve inches long, to the upper part. In like manner obtain a copper cylinder fitting into the larger vessel, with a similar wire attached. To put the battery together, place the porous jar in the tumbler; the copper cylinder between the two, and the zinc cylinder in the smaller one. Pour diluted sulphuric acid into the small vessel, and a solution of sulphate of copper into the other; both these are easily procured at a chymist's. Five-and-twenty, or more, such cells are used together for the electric telegraph, the wire from one zinc cylinder being always connected with the wire of the copper cylinder in the succeeding cell. If you prepare only one such cell, it will not be strong enough to exhibit sparks, and the other phenomena, when the two ends of the wires are brought together. Hence it will not be advisable to construct only one.

A far preferable cell to the preceding, and almost double as strong, is made with zinc and charcoal, in the following manner: Take common coke, crush it to powder, and moisten this powder in a saucer with concentrated nitric acid, and then pour this into the porous

jar. Then take a solid piece of coke, fasten round the top a copper-wire, leaving about a foot free, and thrust the piece of coke into the porous cell with the powdered coke and nitric acid. Place a zinc cylinder, prepared as above described, in the outer vessel, and let it have a copper wire attached to it; in the outer vessel put diluted sulphuric acid. If the two copper wires are then brought together, a bright, small, and vivid spark will be observable between the two extremities. Care must be taken that the points where the two wires meet are filed every time the cell is used; the smallest film of impurity would hinder the passage of electricity between the wires. When the battery is taken to pieces, all metal parts must be cleaned; the zinc cylinder may be cleaned with brickdust or sand. The diluted sulphuric acid may be preserved, and used again, with the addition of a few drops of strong acid. The powdered coke may be dried, and on the next occasion, moistened again with nitric acid. The porous jar must be rinsed several times with water and put away in some proper place, for it contains nitric acid vapours, which would corrode many metals.

Dr. Reinsch* has given a description of a battery very similar to the preceding, but somewhat more complicated, which is very powerful. His description of its construction is as follows: "Into a common porous cell which will contain two or three ounces of water a cylinder of coke is fitted, through which a hole is bored of about half an inch diameter. Round the cylinder of coke is placed roughly powdered coke, having been separated from the finer dust with a sieve; the powder is moistened with common *aqua fortis*, for which purpose about three ounces are necessary. A brightly-polished piece of iron is fitted into the tube of the coke, and its upper extremity is wound round with copper wire, which

* Dingler's "Polytechnisches Journal" for Feb. 1850, p. 233.

has an eye drilled in the other extremity. A spike of copper is soldered to the zinc cylinder, which is made of ordinary amalgamated zinc-plate; the copper-cylinder of the succeeding coke-cell is connected with the copper spike. Three such cells are sufficient to produce a stream of electricity strong enough to decompose water so rapidly that an apparent boiling is effected near the two poles by the rising of the gases. Two such cells are enough for the operations of gilding and silvering. This construction of a battery may be used for a week in uninterrupted activity, with pretty constant strength. When the effect of nitric acid is exhausted, the powdered coke and the cylinder of the same material may be washed with water and dried; in this manner they may be used for years, as the nitric acid does not attack them. The economy and convenience of these cells for electric experiments will give an opportunity to many of pursuing this interesting part of Natural "Philosophy".

For the following experiments a single cell will be found quite sufficient, and may be constructed with or without the iron rod.

If this battery, which is powerful and very economical, is shown to the pupils, the coke should be already prepared and placed in the jar; the powder is moist, so that the jar contains coke in contact with a fluid. Then the zinc should be placed in the diluted sulphuric acid. Thus we have coke (carbon) and a metal in contact with fluids. The light which appears when the two wires are brought together, is an electric spark; it is attributed to the electricity, which is excited by such an arrangement of metal, carbon, and acids. This extremely subtle substance passes from the coke along the copper wire, and through the spark to the second wire, and to the zinc. In the interior of the battery the stream of electricity flows from the zinc back to the coke. Electricity thus continually circulates, as if in an endless chain.

65.—*Conductors of Electricity.*

When the copper wires in a zinc and carbon battery are brought together, we have seen that an electric spark is produced, and the current passes over the wires. Now take a small piece of dry wood, (a pencil), and hold it pressed against the extremity of one of the wires; if electricity could pass over dry wood, we should see a spark as soon as the pencil and the other wire are brought in contact with each other. But no spark will be perceived; dry wood, then, does not conduct the current, or is a *non-conductor of electricity.*

Again, cover one end of the wire with silk, and bring the other wire near it; electricity does not pass along silk; if this were not so thin no spark would be perceived. On the contrary, if a silver spoon is connected with one of the wires and the other is placed in contact with any part of it, a spark will be visible; electricity can be conducted over silver. Silver and copper are among the best *conductors* of electricity.

66.—*The Electro-Magnet.*

Get a blacksmith to bend a piece of iron into the shape of a horse-shoe; it should be about as thick as a finger; its two shanks about two or three inches long, and separated from one another by the space of an inch; the ends should be smooth and polished. In the preparation of the horse-shoe two things must be observed: it should be made of soft iron, and after it has received the required form, it should be again put into the fire, brought to a red heat, and not taken out again until the fire is burnt out, in order that the iron may be gradually cooled, and without any use of water. By this treatment the iron remains soft, and adapted to convey electricity.

The horse-shoe thus prepared is to be surrounded with silk ribbon or with silk stuff, so that only the two polished ends remain exposed; the silk is to be tied with

silk thread, where it is needful. To complete the preparation, a piece of copper-wire, from seven to ten feet long is required. This wire is to be wound round the silk which covers the horse-shoe. A piece of the copper-wire is left free, and the wrapping round is to be begun at one end of the iron, and continued always in one direction to the other end, where a little of the wire should also remain free. In winding round the wire, the coils should be as numerous as possible, yet without one touching another, and for the size of magnet that we have given, they may be from 50 to 80 in number. It is advisable to examine the coils separately, so that if any two touch they may be separated, or to bring others nearer, where this can be done without their touching. The coils should be most numerous at the two poles, and fewest at the curve of the horse-shoe.

The ends of the wire that hang over are to be polished with a file, and placed in contact with the two conducting wires from a zinc and carbon battery. Let some one else put a piece of iron (a key) near the two poles of the horse-shoe, it will approach nearer, and will be attracted with considerable force by the horse-shoe. Thus the horse-shoe exhibits the same property of attracting iron as a magnet does. Whence does it receive this power? As it did not possess this quality before, it has evidently obtained it through the current of electricity from the battery. The current passes from the battery along one part of the wire round the horse-shoe, circulates through all the windings, and passes out at the other end into the battery again. If the horse-shoe had not been surrounded with silk, the electricity would have passed into the iron itself, and have returned to the battery by the shortest way; as it is, it is obliged to circulate round the iron. *Thus iron becomes magnetic when electricity circulates round it.* The instrument described is called an *electro-magnet.*

67.—*The Electric Telegraph.*

Consists in its principal features of an *electric battery*, and of an *electro-magnet.* The battery is placed where the signals are to be given; the magnet at the other station at which the signals are to be received. When it is desired to render the electro-magnet, at the other station, magnetic, we must have two wires stretching between the stations, if we proceed, as in experiment 66. Our railways have only one wire carried to the second station. Instead of the second wire, a large plate of metal is put in contact with one of the conductors of the battery: the metal-plate being buried deep enough in the earth to be always moist. So, the electricity passes along into the plate, and from it, into the earth, which is a good conductor; it travels through the earth for miles to a similar plate, buried at the second station, which is in contact with one wire of the electro-magnet. The second wire of the electro-magnet is in contact with the copper-wire, which travels along the side of the railway, and is attached to the battery. Thus the electricity from the battery circulates through the earth. to the electro-magnet and along the copper-wire, back again to the battery. It passes over the space of several miles in less than a moment.

The process may be, in some sort, exhibited to the pupils in the following manner: the battery is to be put on a table in a corner of the room, and the electro-magnet on a second one at the opposite end of the room; two long copper-wires are requisite to establish the contact between the battery and the magnet, whose ends are to be filed smooth and kept in contact with the wires of the two instruments at both ends by twisting small wire round the places where the wires join one another; one, only, of the places being left free at the end where the battery stands. It is evident, then, that when the last mentioned are put in contact, the circuit will be com-

plete. Let some one else hold these, and he will represent the person telegraphing. How it is possible to make signals may be made evident in the following manner: Hold a key loosely, and in a horizontal direction, close to the poles of the electro-magnet. At the same time place the right hand upon the magnet, and press, with the fore-finger, against the key, as if to keep it away from the magnet. Now, if the assistant at the other end completes the circuit, immediately electricity will pass round and round the magnet, and make it attractive; it will attract the key. This itself may be used as one signal whose meaning shall have been previously determined. Directly the assistant breaks the circuit, the key being no longer attracted, is kept at a distance by the fore-finger. This is the second movement of the key, and may have a second meaning attached to it. Corresponding to the key in our experiment is a piece of iron at the telegraph-station, suspended in a suitable position before the electro-magnet; and, instead of a finger, there is a spring, against which the iron presses. When the circuit is completed at the station, the iron is attracted; and when the circuit is broken, the spring draws the iron away. Thus signals can be made at a distance of several miles by this piece of iron, and its motion backwards and forwards may have several meanings, *e.g.*, the first motion may mean the letter *a*, the first *and* second *b*, &c.

Because this proceeding in practice would be too complex, the piece of iron is attached to a wheel, and the wheel carries a pointer, which travels over a circular disk, on which are inscribed the letters of the alphabet, figures, &c. The more frequently the iron is attracted and set free, the further will the index travel on the disk. By this motion it will point out different letters. Thus every word is spelt by the process of telegraphing.

N. B.—When the electro-magnet is made of soft iron, it loses almost all its attractive power when contact is

broken; should it happen that the instrument does sensibly attract when contact is interrupted, it will be a proof that the iron is not sufficiently soft. This evil may be remedied by placing a thin piece of pasteboard in front of the poles of the magnet, so that the iron shall not come into actual contact with them.

68.—*Electro-typing.*

Take, in addition to the zinc-and-carbon or zinc-and-copper battery, which are equally suited for electrotyping, a common tumbler, and partially fill it with a solution of sulphate of copper. Then fasten a large iron nail to one of the conducting wires, which is to be bent so that the nail may dip into the sulphate of copper; the other wire from the carbon end of the battery, is also to be dipped into the solution. As the wires do not touch one another, the electricity must pass through the fluid. The nail will soon be coloured red with a coating of new copper, and is said to be coppered over by galvanism. Sulphate of copper is a compound body, and is composed of copper and sulphuric acid. Galvanic-electricity has the property of decomposing many compound bodies, and resolving them into their elements. Thus it is that sulphate of copper is decomposed. and the copper settles on the nail; the coating will become thicker the longer the nail is left in the solution. In a similar way, but requiring more precautions, articles may be covered with gold and silver, these metals having been first dissolved in acids.

Take away the nail, and bend the extremity of the copper wire round a penny, and immerse it in the copper solution; if this is left for a little time, it will be covered with new copper, and after a few days the coating will become thick enough to admit of its removal, by filing the edges cautiously. This impression will, of course, be the reverse of the penny, the elevated parts of

the coin will be depressed in the copy, and *vice versa.* If this copy is made to replace the penny, we shall obtain a second, which will be the exact counterpart of the coin. Thus we may obtain correct copies of medallions, &c.

69.—*Electricity by Friction, and Lightning.*

A.—Procure a glass-tube, about two feet long and two inches in diameter, close up one end with a bung pierced with a hole; attach to the bung, by means of a peg, a ball of wood about two inches in diameter, and covered with tin-foil or with silver-leaf. In addition, place a wire in connection with the ball, pass it through the cork, and let it hang down in spirals in the interior of the tube, for about half its length. If the tube is rubbed with a cloth with some force, and the knuckles brought near to the ball, a crackling spark will be emitted, larger but not so bright as that produced in the galvanic battery. This also is electricity, produced by the rubbing of the glass, and called, for the sake of distinction, *electricity by friction.* The electricity excited in the glass flows to the wire, and from it to the ball, where it is accumulated, like a mass of water on an elevation, and only wanting a path in order to flow down to the valley. When the hand is brought near to the ball, the electricity flows over it and the body into the earth. Thus produced, it differs from galvanic electricity in not circulating, but it flows in all directions.

B.—The following experiment, sufficiently easy for the pupils to perform themselves, may be taken as an evidence of the tendency of electricity to flow in all directions, and to spread over neighbouring bodies. Take a sheet of good writing paper, and cut a strip lengthwise, about two inches broad; warm the strip over a lamp, or at the fire, and place it on the table; then, if india-rubber be passed several times over it, it will become electric, and adhere pretty strongly to the table. Take

up the strip, and bring the other hand near it, and the paper will approach towards the hand, in order to share its electricity with it. The paper must be warmed every time the experiment is performed.

C.—Rub the glass-tube; electricity will accumulate in the ball. Bring a key near it, and a spark will appear; metal is a good conductor of electricity (cf. Exp. 65). Paragraph *A* of this Experiment has shown that our bodies also are conductors of electricity. Electricity passes to conductors, because by means of them it passes into the earth. If, on the contrary, a stick of sealing-wax is put near the electrized ball, no spark will be seen; it is not a conductor. This phenomenon is observable in lightning. It strikes most frequently upon metal objects and living beings.

LIGHTNING.—Since very large machines had been contrived to accumulate electricity, by whose means combustible bodies were destroyed, metals smelted and animals killed, it occurred to Benjamin Franklin, an American, that lightning was nothing but a large electric spark. When a storm was approaching, he sent up a paper kite, and attached a key to the lower end of the string, from which he obtain electric sparks. Electricity is formed in the air, in a manner unknown to us. The lightning is an electric spark, which illuminates its whole path. and travels in a zig-zag way, because it meets with resistance from the air. Lightning generally strikes prominent objects, especially metàls. *Thunder* is, on a large scale, what the crackling noise is in the electric spark. It originates in the fact that the lightning compresses the air through which it passes, whilst behind the air is rarer. We hear the thunder after lightning, because sound travels more slowly than light; and the longer the interval between them, the further is the storm from us. When lightning issues from a storm cloud near us, we hear only a single clap of thunder, but if the lightning

passes over a long path, at every bend in its cou
new peal is produced, which causes the rumbling or
ing noise observable in distant thunder.

The chief precautions in a thunder-storm are
remove from the neighbourhood of all high and go
conducting objects, such as spires, single trees, and i.
the house, to keep away from larger metallic bodies, or
from chimneys, whose soot and smoke are good conductors.

Since lightning goes to conductors, Franklin thought of placing high metal rods, as a protection, and invented what are called *lightning-conductors.* They are placed above the highest parts of the building, and are in metallic connection with the ground. If the lightning should strike them, all electricity will pass by them into the earth, without injuring the buildings at all.

THE END.

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